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PRELIMINARY TESTS OF THE STEPHENSON VALVE - 2ND REPORT

BY

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ABSTRACT

The Stephenson blast valve consists essentially of a resilient media in a steel tube or other blast resistant container. To study the capability of the valve, numerous tests were made on different resilient media with respect to their resistance to air flow, blast attenuation and dust arrestance. The most successful media was a combination of non-porous polyurethane cylinders (1-3/4-inch dia. x 1-inch long) and cylinders of the same material and size with a porosity of 20 pores per inch. The ratio was 1:1 and the depth 12 inches. The air flow was 103 cfm through an 8-inch tube, or about 300 cfm per square foot, with an air resistance of 1-inch water. When subjected to an overpressure of 76 psi with a duration of 2 seconds, the initial impulse in the surge chamber was 0.25 lb sec/sq inch. The performance of the media as a prefilter was excellent.

A problem in the use of the media as tested was its tendency to remain in a semi-compressed condition after being subjected to a high overpressure. The cylinders appeared to be too large for the 8-inch dia. tube.

More preliminary work is required before a design can be finalized.

INTRODUCTION

In 1963 the concept of the Stephenson blast closure valve and the results of early tests on the valve were described in a preliminary report.[1] Since that time the valve has been more thoroughly investigated and this report presents new data and a more detailed discussion on its capabilities. The concept of the valve, which consists essentially of a resilient media in a steel tube, has not changed but new tests have been carried out on resilient materials of different porosities and at different depths. Air flow tests were also carried out. Although the results are very encouraging there are still some design problems and many more materials and material configurations for the interior of the valve which could be tested and evaluated.

DESCRIPTION

The valve considered in this series of tests consists of a steel tube partially filled with a resilient media in the form of cylinders and an integral surge chamber. The tube is made of schedule 40 steel and has a nominal diameter of 8 inches. The lower perforated plate which supports the resilient media is 3/4-inch steel containing 89 holes of 1/2-inch diameter and the upper plate is 1/2-inch steel with the same number of holes. The upper plate is needed for closure during the negative pressure phase at which time the media would be lifted up and pressed against it. A portion of the tube extends beyond the lower plate to form the surge chamber.

The resilient media made of polyurethane was in the form of cylinders 1-3/4-inch diameter and 1-inch long. The polyurethane tested was either nonporous or had porosities of 20, 45 or 60 pores per inch. Tests were also made on a mixture of nonporous and 20 ppi cylinders.

The test equipment with the valve in place is shown in Figure 1. It is the same equipment used in previous tests except the method of rupturing the diaphragm was changed to give a steeper pressure pulse. When the desired air pressure has been reached in the supply tank, the diaphragm is now ruptured by a wax projectile shot from a modified 22 caliber rifle. As before, vents 1 and 2 immediately open, allowing a portion of the supply air to escape to atmosphere thereby creating a pressure profile at the valve similar to the positive pressure phase of an atomic explosion.

Pressure cells are located in three places, (1) just above the resilient media, (2) in the surge chamber, and (3) in the plenum which is an air tight tank.

The valve has an area of 1/3 of a square foot, the surge chamber has a volume of approximately 1/6 of a cubic foot, and the plenum has a volume of 45 cubic feet. The plenum was kept disproportionately small for the valve so an indication of the leakage through the valve and the type of pressure pulse could be readily determined.

PROCEDURE

Air Flow Tests

Measurements of air flow vs. air resistance were made on the following resilient media:

a. nonporous polyurethane at 6-inch, 12-inch and 24-inch depth

b. 60 ppi polyurethane at 12-inch and 24-inch depth

c. 45 ppi polyurethane at 12-inch and 24-inch depth

d. 20 ppi polyurethane at 12-inch and 24-inch depth

e. 1:1 combination* at 12-inch and 24-inch depth

*(nonporous and 20 ppi cylinders in a 1:1 ratio)

Results of Air Flow Tests

Air flow tests on the perforated plates and resilient media were performed separately. The data on air resistance vs. air flow have been plotted and are shown in Figures 2 and 3. The air flow is also given for a cross sectional area of 1 square foot.

Blast Attenuation Tests

Most of the blast attenuation tests were carried out with the valve in the position shown in Figure 1, that is, with the valve connected directly to the plenum. However, a few shots were made without the plenum and the bottom plate so that the valve discharged directly to the atmosphere.

Tests were made with overpressures varying from 5 psi to 104 psi on different depths of the cylinders. Complete data on the shots is given in Table I of the Appendix. This information also includes data on one shot where the cylinders were preheated.

Discussion of Results of Blast Attenuation Tests

In selecting the media with the most desirable characteristics the degree of blast attenuation and the air resistance had to be weighed against each other. For general usage the following media were eliminated from consideration because the air resistance was too high:

a. nonporous at 6-inch, 12-inch and 24-inch depth.

b. 60 ppi, 45 ppi and 1:1 combination at the 24-inch depth.

(See Figures 2 and 3). The results on blast attenuation are given in Table I of the Appendix.

The blast attenuating characteristics are somewhat difficult to evaluate because the allowable overpressure or impulse on the downstream side of the valve is dependent on the system with which the valve is associated. For example, the valve may be followed by a fan, a coarse filter, and an absolute filter in that sequence. On the other hand, the fan may be located on the downstream side of the absolute filter which would put a more stringent condition on the valve. It is currently more popular, however, to place the fan between the valve and filter. Unfortunately, like all mechanical equipment, the fan's tolerance to overpressure and its blast attenuating characteristics are unknown and consequently its protection to the absolute filter can only be estimated.

In studying the results in Table I of the Appendix, it can be seen that the overpressure in the plenum never exceeded 7 psi and this pressure was reached gradually over a period of 1 to 3 seconds. If the plenum had been open to the atmosphere through a collective protector, it is doubtful if the pressure in the plenum would have reached more than 1 psi and the collective protector would have been unharmed. Although the nonporous cylinders at the 12-inch depth performed best, the combination cylinders at the same depth are almost as good and since they have less resistance to air flow they have been selected as most suitable.

To illustrate the performance of the 12-inch depth of 1:1 combination cylinders, Figure 2 shows the air flow characteristics and Figure 4 shows its ability to attenuate blast. The overpressure in the surge chamber varied with the applied overpressure but in all cases the impulse was in the order of 0.25 lb sec/sq inch, which was a very small percentage of the applied impulse. The overpressure in the plenum never exceeded 4 psi.

The effect of heat on the 1:1 combination 12 inches deep was determined by heating the cylinders to 130 F, placing them in the tube and subjecting them to an overpressure of 98 psi. There was no noticeable change in their resiliency and although the overpressure in the surge chamber reached 45 psi, the pressure in the plenum reached only 4.5 psi.

The effect of cold on all of the media was observed by placing them in a cold chamber at -20 F. Their resiliency was definitely reduced but they warmed up so quickly that it was impossible to subject them to an overpressure fast enough to give meaningful results. To test them properly it would be necessary to draw cold air through the media until the whole system was reduced in temperature and then quickly apply the overpressure. This type of testing which requires low temperature refrigeration did not seem justified at the present time.

Dust Arrestance Tests

Over the past few years dust arrestance tests have been made on many different kinds of filters at NCEL, using equipment especially designed for this purpose. A photograph of the equipment and a detailed explanation of its operation is given in Reference 2.

Dust arrestance tests were given to the following resilient media to determine their filtering capability.

a. 1:1 combination at 12-inch depth.

b. Nonporous at 12-inch depth.

c. 45 ppi at 12-inch depth.

The cylinders were placed in a 8-inch by 8-inch tube and the velocity of the air through the tube was fixed at 338 fpm, which gave a pressure drop of 1-inch WG before the dust was admitted. Each media was tested in the following manner: (1) the media was subjected to the air stream for 30 minutes into which the 0-5 micron dust[3] was being fed at the rate of 20 grams per hour. This was done to obtain the initial arrestance value of clean media, which is the measurement generally given in the manufacturers' literature. (2) The media was then loaded by subjecting it for one hour to the AFI Standard Test Dust[4] being fed into the air stream at the rate of 40 grains per hour. The media was again subjected for 30 minutes to the 0-5 micron dust being fed into the air stream at 20 grams per hour. Each succeeding run was a repeat of the second and third step until a total of 210 grams of dust had been discharged against the cylinders. Based on 20-inch by 20-inch nominal sized filters which were used for tests described in Reference 2, the total dust loading would equal 1090 grams.

Resistance was determined by an inclined manometer and was measured before and after each step of the test procedure.

Results of the Dust Arrestance Tests

Arrestance and air resistance data is given in Table II of the Appendix.

Figure 5 gives a comparison of the performance curves for the 12-inch depth combination cylinders and three of the best filters (A, B & C) previously tested at NCEL. Filter "A" was a 2-inch thick metal viscous impingement type, Filter "B" was a 4-inch thick metal viscous impingement type and Filter "C" was a 2-inch thick fibrous type.

Discussion of Results

The efficiency of the 6-inch and 12-inch depth nonporous cylinders dropped off rapidly which was understandable since they do not have interstices in which the dust can collect.

The efficiency of the 12-inch depth 45 ppi cylinders was excellent but the air resistance increased at a rather fast rate.

The efficiency of the 12-inch combination cylinders was also excellent and the pressure loss remained almost constant which made it rather outstanding as a filter. The dust particles seemed to collect deep in the 20 ppi cylinders without seriously obstructing the path of the air flow. The efficiencies at the low and medium levels of dust loading are very important so the superiority of the combination cylinders over the commercial filters is easily seen. The media can be treated with a viscous substance if dust retention during an atomic blast is required.

FINDINGS

The following is a list of the findings of the Stephenson valve, with comments on further exploration and testing which would be required before a final design could be determined.

1. The valve operates successfully over a range of overpressures from 5 psi to 100 psi.

2. The valve has no bearings or machined mating parts which would require corrosion protection and regular inspection.

3. Air flow rates through the valve are not critical. If fan capability is available, the valve can handle at least twice its normal flow with no problems.

4. The valve is compact in size and not fixed to any dimension other than a sufficient depth to house a 12-inch depth of resilient media.

5. The valve serves as a prefilter.

6. Fabrication of the valve does not require highly skilled labor.

7. In the series of blast attenuation tests just concluded, the cylinders sometimes remained in a semi-compressed state due to bridging. The cylinders appeared to be too large for the 8-inch diameter tube.

8. The resilient materials are not fireproof; however, the valve could undoubtedly be designed to protect it against thermal radiation from the fireball in the 100 psi range.

9. It is possible that if air at low temperatures (-20 to -40 F) was drawn through the resilient materials, their effectiveness in shutting out the blast might be impaired. Wire heaters could be used to prevent this, however, just as heaters might be needed to prevent icing on metal valves.

FUTURE WORK

The preliminary work which has been done to this point indicates that more work is necessary before a design can be finalized. The main problem to be overcome is restoration of the media after blast, which will require testing smaller cylinders or other geometrically shaped objects. The inclusion of a small percentage of highly resilient material may be necessary.

The use of a thin layer of gravel preceding the balls should be investigated for fire protection. Information should also be obtained on the use of flame retardant silicone elastomers.

The effect of adding a viscous substance to improve dust retention should be explored.

CONCLUSIONS

1. Among the various media tested, the 12-inch depth of combination cylinders provided the best compromise between blast attenuation and resistance to air flow.

2. The 12-inch depth of combination cylinders proved to be an excellent pre-filter.

3. The problem of bridging requires further investigation.

4. More preliminary work is required on the resilient media with respect to material and form.

REFERENCES

1. U. S. Naval Civil Engineering Laboratory Technical Note N-491: Preliminary Tests of the Stephenson Valve, by J. M. Stephenson and R. S. Chapler. Port Hueneme, Calif., 8 March 1958.

2. U. S. Naval Civil Engineering Laboratory Technical Note N-287: Arrestance, Resistance, and Dust-Loading Tests on Commercial Air Filters, by Ernest N. Hellberg and William R. Nehlsen. Port Hueneme, Calif., 1 February 1957, Figure 1.

3. Ibid., p 3.

4. Ibid., pp 4-5.

Appendix

Table I. Blast attenuation test data.

Shot No.	Applied overpressure (psi)	Time duration (sec)	Overpressure in surge chamber (psi)	Time duration (msec)	Overpressure in plenum (psi)
		6-inch depth nonporous			
1	106	3	13.8	250	2.8
2	79	2	15.6	225	2
3	77.5	3	16.2	225	2
4	47.5	1.5	15	225	2
		12-inch depth nonporous			
5	104	3	15.6	17	0.4
6	81	2	18.0	17	0.4
7	72	2	18	12	0.4
8	51	1.75	10.8	12	0.4
		24-inch depth nonporous			
9	95	3	21	21	0.3
10	65	3	31.8	21	0.4
11	70	1.75	3.6	12	0.5
12	44	1.75	3.6	12	0.2

Table I. Blast attenuation test data (cont'd)

Shot No.	Applied overpressure (psi)	Time duration (sec)	Overpressure in surge chamber (psi)	Time duration (msec)	Overpressure in plenum (psi)
		24-inch depth 20 ppi			
13	73.5	1.0	50	*	7.3
		12-inch depth 45 ppi			
14	102	2	28	*	7
15	76	1.75	16	175	4
16	59	1	33	500	7
17	49	1.25	11	37	5
		24-inch depth 45 ppi			
18	102	2.25	18	*	6
19	63	1.5	28	33	3.6
20	67	1.25	14	37.5	5
21	41	1.0	11	37	3
		12-inch depth 60 ppi			
22	89	1.5	19	*	6
23	65	1.0	18	50	5
24	65	1.0	17	50	5
25	44	1.5	11	37	6

*Over a time duration of 300 to 500 msec the pressure curve in the surge chamber was characterized by a sharp peak followed by one or two gradual pressure rises.

Table I. Blast attenuation test data (cont'd)

Shot No.	Applied overpressure (psi)	Time duration (sec)	Overpressure in surge chamber (psi)	Time duration (msec)	Overpressure in plenum (psi)
			24-inch depth 60 ppi		
26	89	1.5	19	*	5
27	65	1.75	18	35	5
28	65	1.75	18	35	4
29	40	1.0	14.5	35	3
			6-inch depth combination (1:1)		
30	96	1.75	56	250	6.2
			12-inch depth combination (1:1)		
31	76	2.0	18	21	3.6
32	65	1.75	27	25	4
33	57	1.5	18	29	3
34	37	1.0	11.4	21	2
35	24.5	1.25	10	29	2.1
36	5.6	0.75	2.0	20	1.0
			24-inch depth combination (1:1)		
37	72	2.5	25	25	4
38	65	2	29	41	2.5
39	59	1.75	6	25	2.5
40	41	1.25	3	21	1.5

Table I. Blast attenuation test data (cont'd)

Shot No.	Applied overpressure (psi)	Time duration (sec)	Overpressure in surge chamber (psi)	Time duration (msec)	Overpressure in plenum (psi)
6-inch depth combination (1:1) open end					
41	79	2 - 3	8.4	1	NA
12-inch depth combination (1:1) open end					
42	92	3	4.5	1	NA
12-inch depth combination (1:1) media heated to 130 F					
43	98	2	45	17	4.5

Table II. Dust Loading Data

Weight of test dust fed (grams)	Media: 12-inch depth combination		12-inch depth nonporous		12-inch depth 45 ppi	
	A*	R**	A	R	A	R
10	68.8	1.00	59.1	1.00	77.5	1.00
60	81.4	1.00	62.9	1.01	80.1	1.19
110	76.8	1.01	47.1	1.03	74.8	1.35
160	79.6	1.02			82.8	1.48
210	59	1.07			77.7	1.60

*A = arrestance in percent

**R = resistance to air flow - inches of water

Note: Air velocity equalled 338 fpm in all cases.

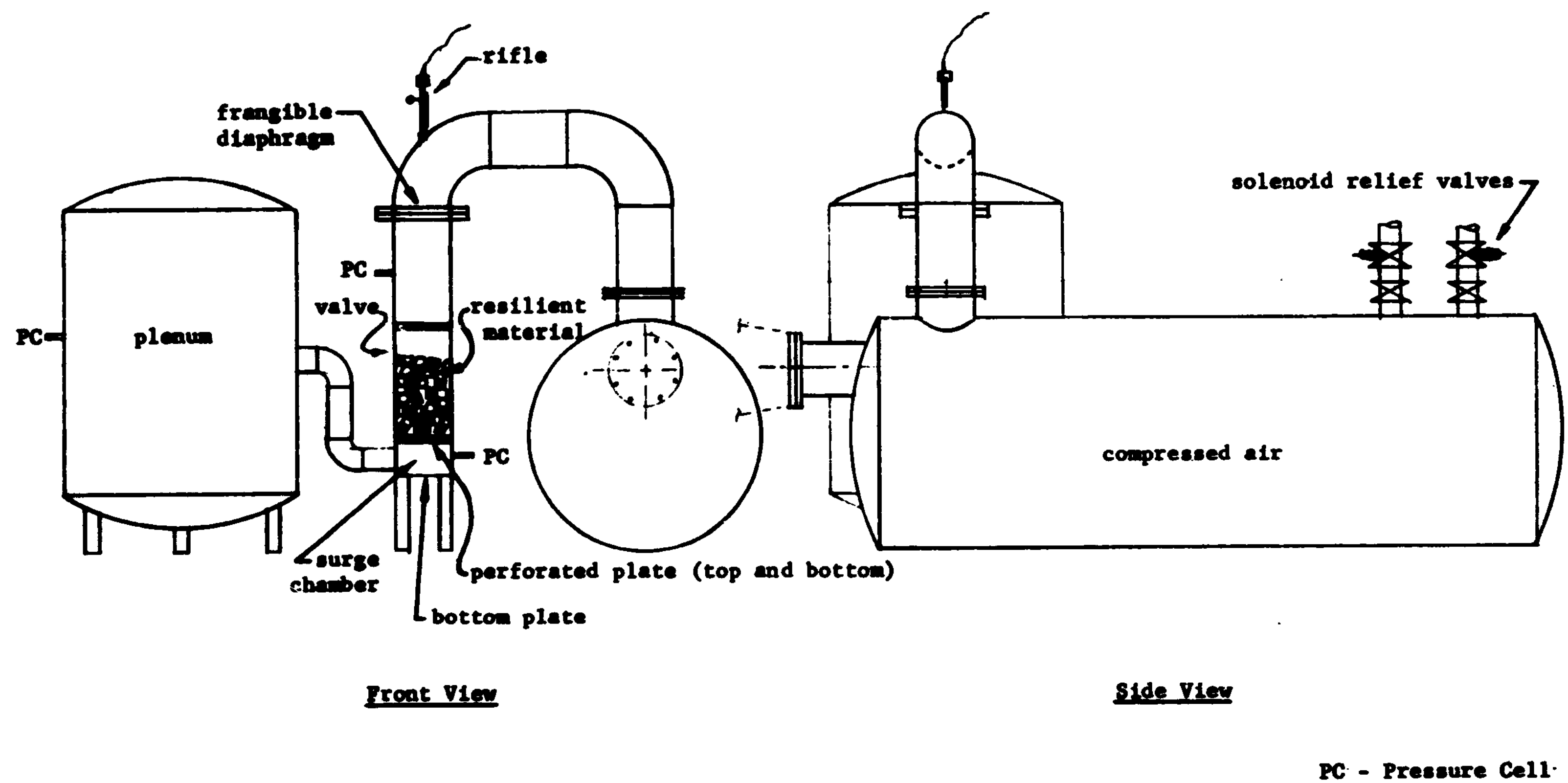

Figure 1. Valve ready for blast attenuation tests.

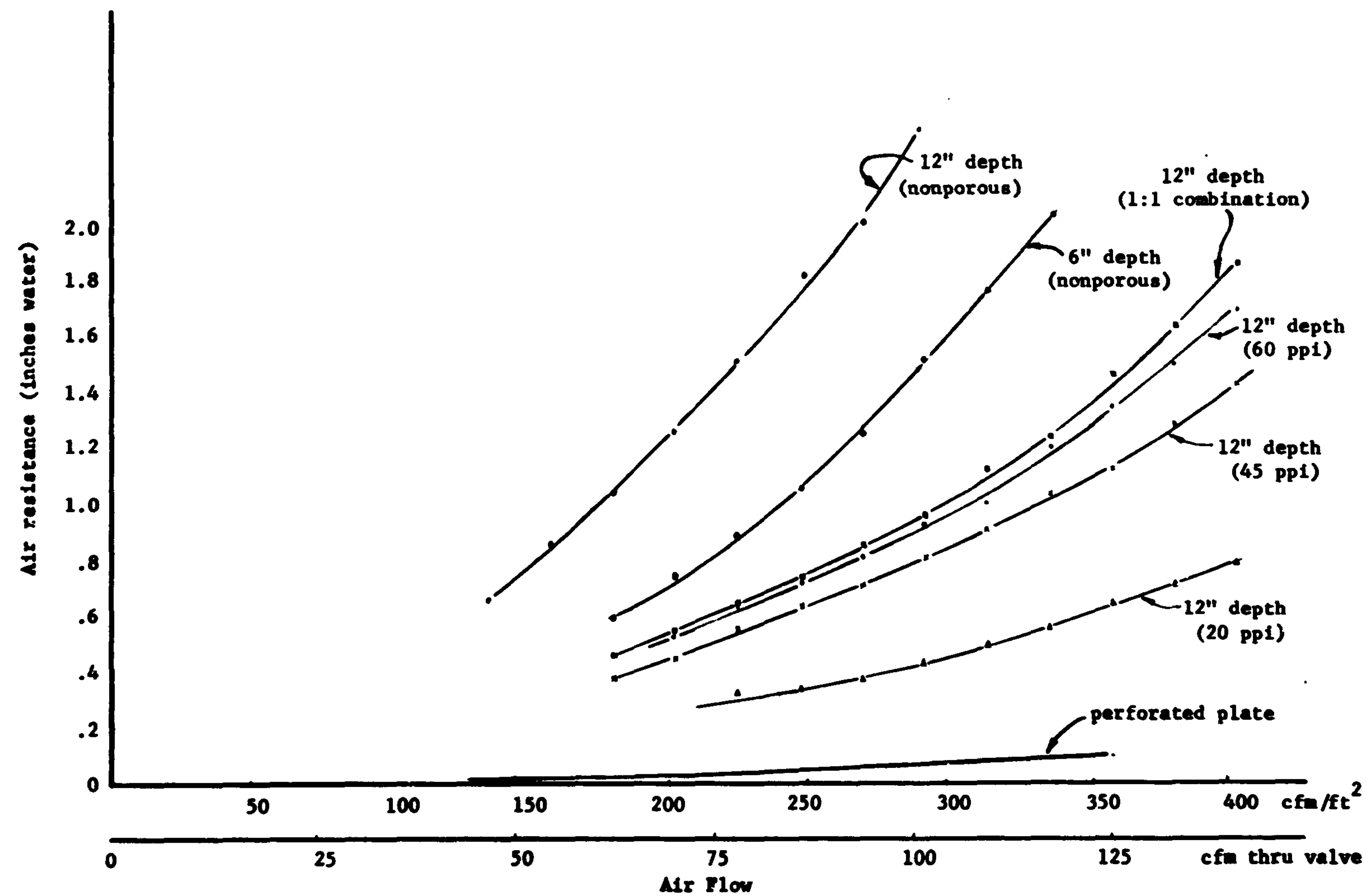

Figure 2. Air resistance of 6-inch and 12-inch media and perforated plates.

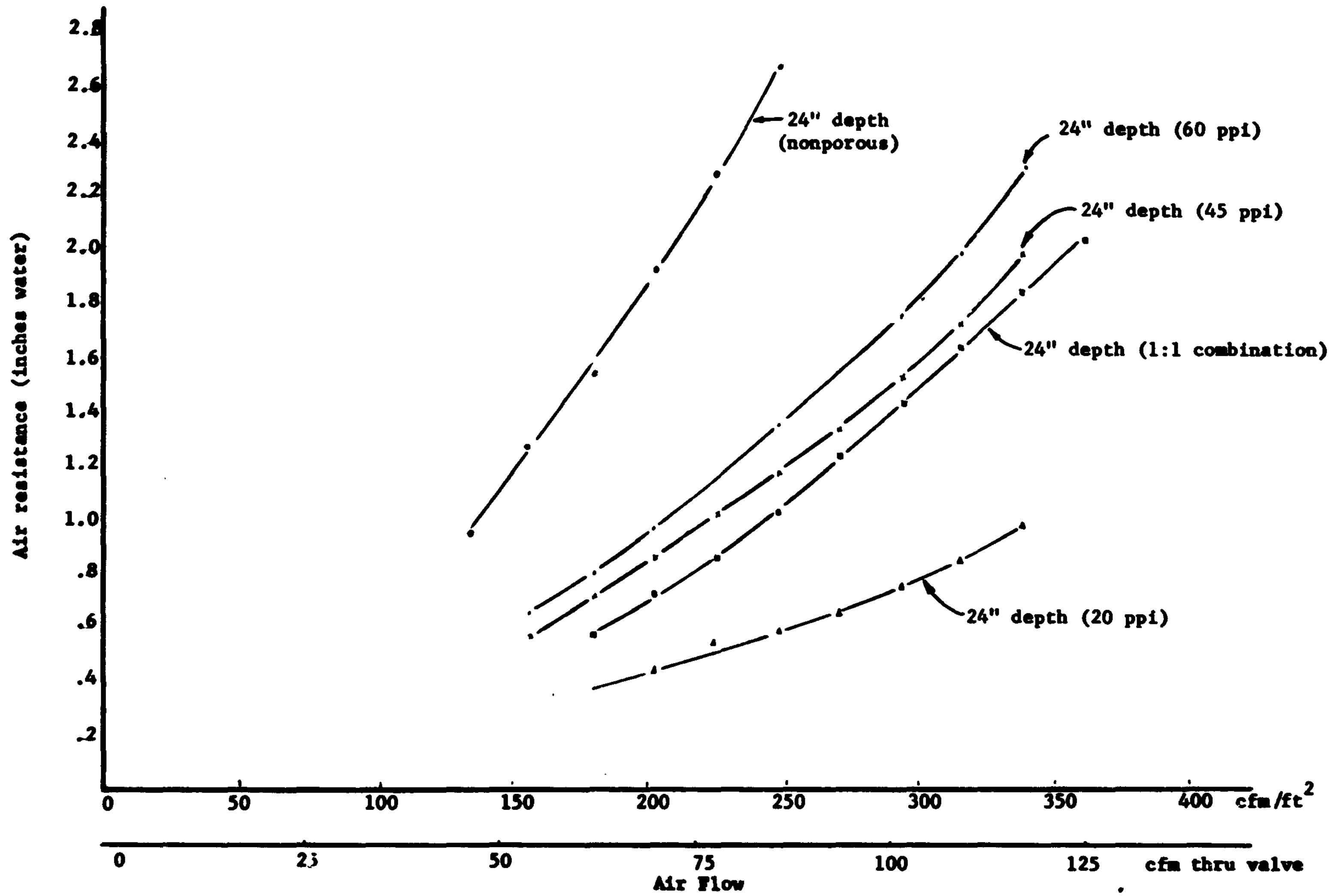

Figure 3. Air resistance of 24-inch media.

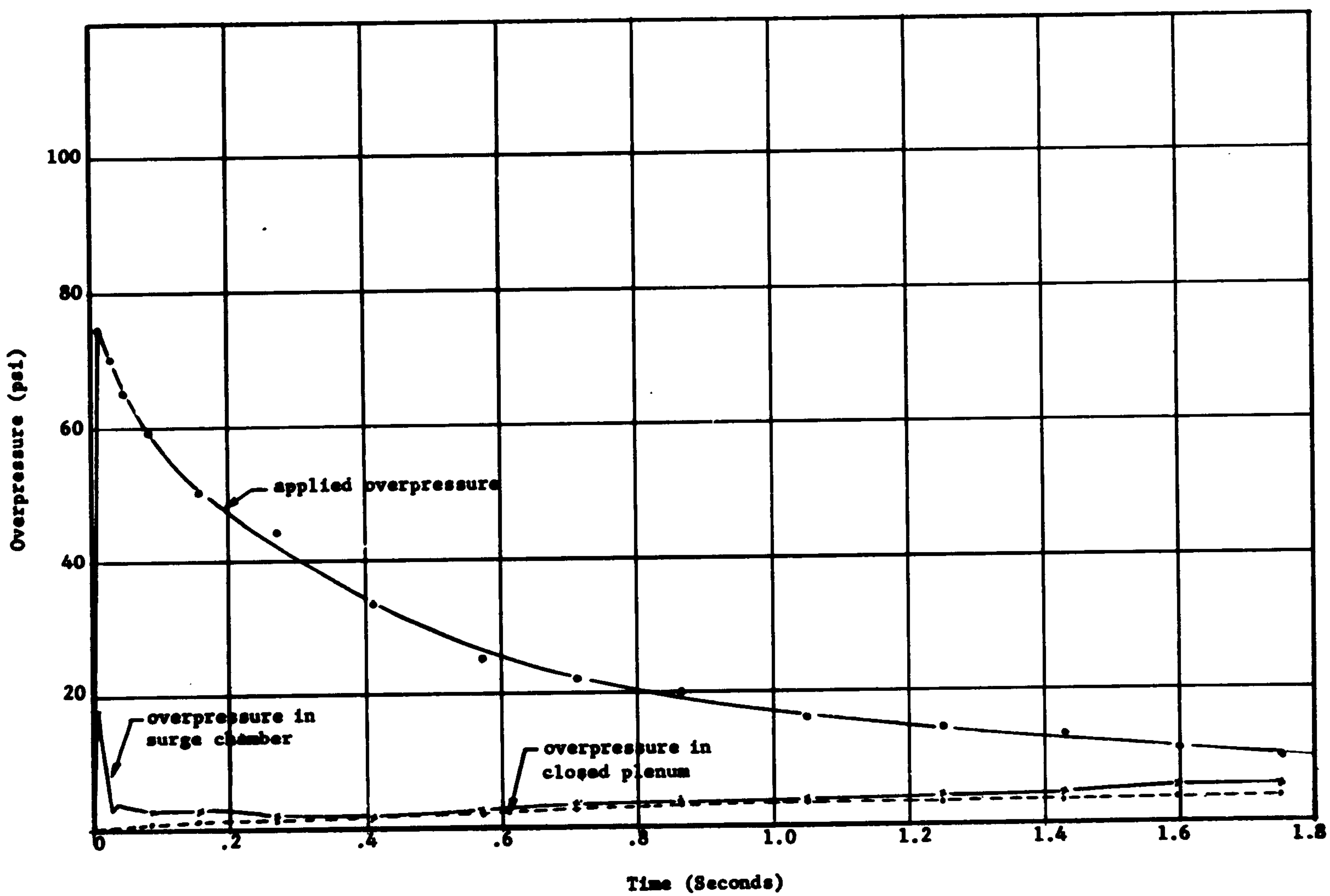

Figure 4. Pressure attenuation of valve with 1:1 combination cylinders 12-inches deep.

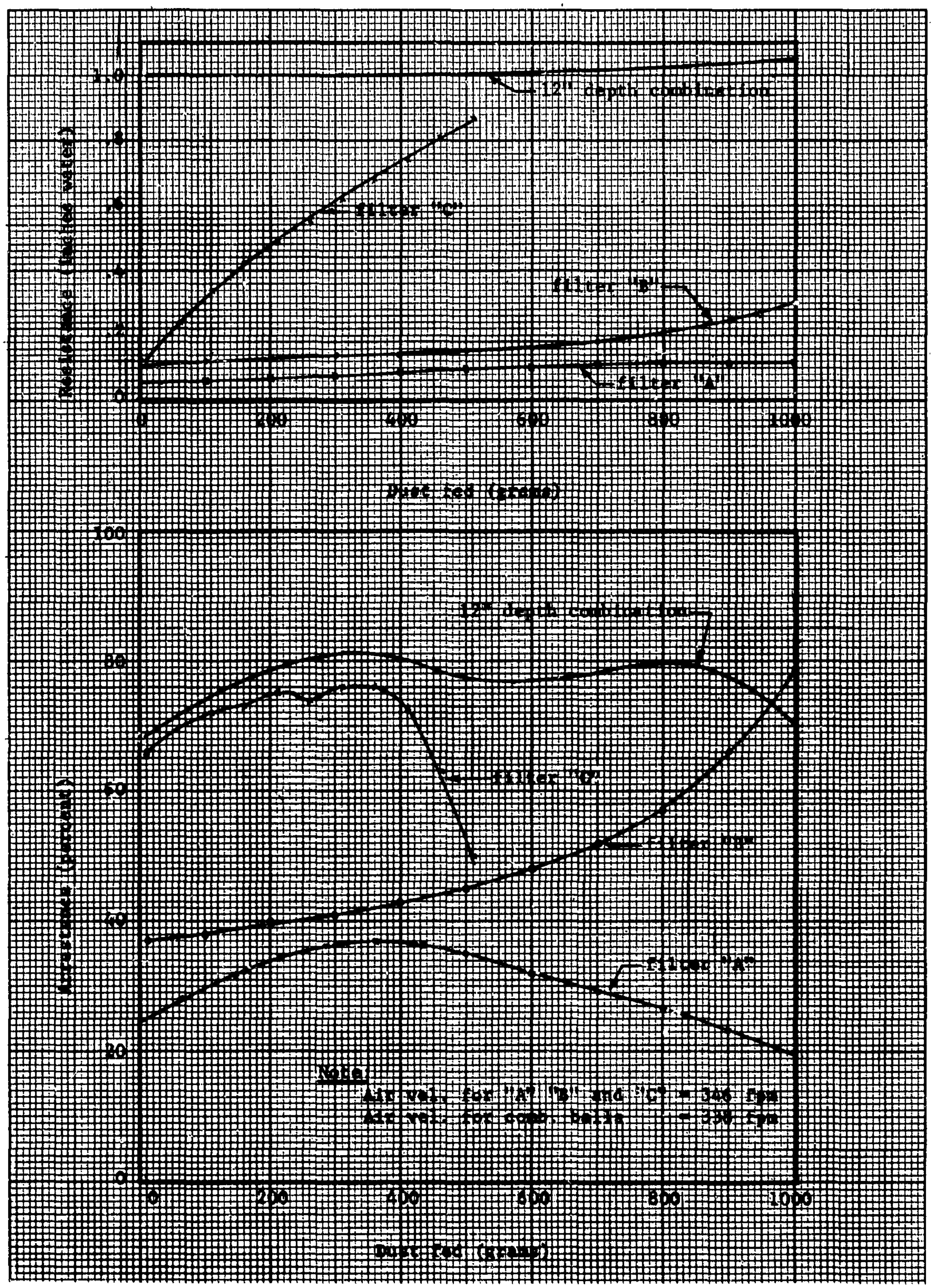

Figure 5. Comparison of combination cylinders with three commercial filters.